# THE CLASSIFICATION OF THE UPPER CRETACEOUS FORMATIONS AND FAUNAS OF NEW JERSEY[1]

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Since the organization of the present Geological Survey of New Jersey, three classifications of the Cretaceous formations of the state have been proposed and have been published in the reports of the Survey. The first of these, elaborated by Professor Cook during his administration as state geologist, was published in 1868.[2] At that time the practice of naming geological formations by geographical names was not usually adopted by working geologists, and the successive beds were designated by names suggested by their lithologic characters. Above the "plastic clays" since known as the Raritan formation two major series of beds were recognized, the "clay-marl" series below and the "marl" series above. The discrimination of the beds of the "marl" series, as first described by Cook, has not been changed by any of the more recent investigations, but a closer study of the "clay-marl" series has led to the discrimination of a series of beds not recognized by Cook. In his interpretation of the stratigraphy of the southern portion of the area, however, Cook, in the absence of accurate topographic maps, fell into one error on account of his failure to recognize the disappearance of his "red sand" formation in that direction, and the consequent continuity of the "lower" and "middle" marl beds. To the south he identified a bed now known to belong in the "clay-marl" series, with the "lower marl" of Monmouth County, and considered the bed now known to represent the combined "lower" and "middle" marls, to be the continuation of the "middle" marl alone.

In 1891 Professor W. B. Clark entered upon a study of the Cretaceous beds of New Jersey, and the results of his work are published in the *Annual Reports* of the Survey for 1892, 1893, and 1897. The

[1] Published by permission of the State Geologist of New Jersey.

[2] *Geology of New Jersey*, 1868, p. 241.

two essential differences between his classification and that of Cook are in the position of the major dividing line between what are, roughly speaking, Cook's "clay-marl" and "marl" series, and in the interpretation of the "yellow sand" formation above the "middle marl." In place of Cook's lithologic names, however, Clark substituted a series of geographic names in accordance with more modern usage. In a more recent paper Clark[1] has made some modification of his earlier interpretation of the beds, notably in the position of the lower boundary line of his lower or Matawan division in the region adjacent to Raritan Bay. In this paper he has excluded the Cliffwood clays from the Matawan, thus bringing the basal line of the Matawan to conform exactly with the base of Knapp's Merchantville clay.

During his study of the Pleistocene deposits under the direction of Professor R. D. Salisbury, Mr. G. N. Knapp found it necessary to make close study of the underlying formations of Cretaceous age. In the course of this study he was able to discriminate a series of five distinct formations in the old "clay-marl" series of Cook. Each one of these formations was found to be marked by constant lithologic characteristics, but at that time the paleontologic characters of the beds had not been investigated. These formations were traced by Knapp and carefully mapped entirely across the state from Monmouth to Salem Counties. A description of the beds, especially in relation to the soils to which they give rise, was first published by Professor Salisbury in the 1898 *Report* of the Survey,[2] and geographic names were applied to them, viz., Merchantville, Woodbury, Columbus, Marshalltown, and Wenonah. A fuller description of the lithologic characters of these formations has been given by Dr. H. B. Kümmel in the recent *Clay Report* of the Survey.[3]

[1] *American Journal of Science*, 4th series, Vol. XVIII, pp. 435–40.

[2] *Annual Report of the State Geologist of New Jersey*, 1898, pp. 35, 36. It may be said that the tracing out of the Cretaceous beds was no part of Professor Salisbury's plan. It was done by Mr. Knapp because the several beds of the "clay-marl" series sustained very definite relations to the Pleistocene formations. The names published at this time were not published by Professor Salisbury for the purpose of making a new classification of the Cretaceous, but merely because the soils could best be described in connection with these several subdivisions.

[3] Geological Survey of New Jersey, *Final Report*, Vol. VI, pp. 152–61.

These three systems of classification have been arranged side by side in the accompanying tables, in order that they may be easily compared one with the other.[1] At the time of publication of Cook's classification, although a large number of Cretaceous fossils had been described from New Jersey, little was known of the actual distribution of the fossil species in these beds, except in the case of the conspicuous shell beds which can be recognized continuously across the state. Cook's classification may therefore be considered as being based almost exclusively upon the lithologic characters of the beds. Before Clark's classification was proposed, however, Whitfield's[2] two important volumes upon the paleontology of the Cretaceous formations of New Jersey had been published, and Clark gives long lists of fossil species in his papers as representative of the faunas of his major divisions, so that his classification was founded, at least in part, upon paleontologic data. Knapp's subdivisions of the "clay-marl" series are professedly based upon the lithologic characters alone.

During the field seasons of 1903 and 1904 the writer has been engaged in an investigation of the paleontology of these Cretaceous beds and has accumulated a large amount of information in regard to the faunas of the successive formations, especially those of the "clay-marl" series, and in the following pages an attempt will be made to point out the bearing which this new evidence has upon the classification of the formations and faunas.

In his Matawan division, Clark has recognized two formations, the Crosswicks clays and the Hazlet sands. The Crosswicks clays correspond exactly with Cook's "clayey green sand," and with Knapp's two formations, the Merchantville clay-marl and the Woodbury clay; while the Hazlet sands correspond in Monmouth County with Cook's "laminated sands" and with Knapp's two formations, the Columbus sand and the Marshalltown clay-marl, as well as with

[1] In this table Cook's classification of the beds in Monmouth County is recognized. His understanding of the stratigraphy in the south was incomplete, and in that portion of the area he considered Knapp's Marshalltown formation as the equivalent of the "lower marl" and the Wenonah as the equivalent of the "red sand," the true Red Bank sand and the Tinton beds being absent there.

[2] *Paleontology of New Jersey*, Vols. I and II; also *Monographs of U. S. Geological Survey*, Vols. IX and XVIII.

a portion of the Wenonah sand. In his faunal lists Clark does not differentiate the fauna of the Crosswicks clays from that of the Hazlet sand, but gives a single generalized list of species as the fauna of the whole Matawan. As a matter of fact, there is considerable community of characters among the faunas of all five formations recognized by Knapp in the "clay-marl" series, except only the fauna of the upper beds of the Wenonah sand in the southern portion of the area, enough, at least, to make their inclusion in one major division fully justifiable. The two cephalopod genera, *Placenticeras* and *Scaphites*, characterize the whole series of beds, either one or both being present at every locality where fossils have been extensively collected, while neither of them has been detected in the higher beds. There are, however, sharp distinctions between the faunas of the successive formations recognized by Knapp, and these faunal characters are easily recognizable throughout the whole extent of the beds across the state, wherever fossils have been found. In the discrimination of these faunal zones of the "clay-marl" division, however, it is not safe to assert that any particular species is absent from any one of the faunas, and bare lists of species, without some statement of the abundance of the forms noted, might not in all cases show the characteristic features of the different faunules. The combined faunas of the whole series of formations, and even including those to the summit of Clark's Monmouth division, really make one unit of a larger order. The constant recurrence of various species and groups of species, in this entire series of faunal zones, indicates that somewhere along the Atlantic border they lived continuously. As local conditions of environment changed from time to time, the dominant characteristics of the local faunas changed, and it is such changes, for the most part but not wholly, that are recorded in the faunas of these New Jersey formations.

The Merchantville clay is characterized by the abundance, among other species, of *Axinea mortoni*, *Idonearca antrosa*, *Trigonia eufaulensis*, and *Panopea decisa*. In the Woodbury clay these same species are conspicuous for their absence or great rarity. In a collection from the Woodbury clay in Monmouth County, including sixty or more species and many hundreds of individuals, a single specimen of *Idonearca* and a single *Axinea mortoni* were found; while, on the

other hand, *Cyprimeria*, *Lucina cretacea*, *Breviarca*, *Cancellaria subalta*, and others which were rare or entirely absent from the Merchantville, are the commonest species of the fauna. Furthermore, this same faunal distinction between the two beds holds as sharply in the region opposite Philadelphia as in Monmouth County. The faunal lists of the Matawan, heretofore published, omit many of the most abundant and widespread species of the Woodbury clay, and are predominantly of Merchantville species, so that the Matawan fauna as previously recorded is somewhat incomplete.

The Columbus sand has as yet not yielded a single fossil, and is perhaps entirely barren. The Marshalltown formation, however, in its more southern extent is abundantly fossiliferous, although in Monmouth County no fossils have yet been found. Near Swedesboro the fossils in this bed occur in a remarkably perfect state of preservation and in great numbers. A large *Trigonia*, probably *T. mortoni*, is represented by hundreds of individuals, and associated with this species are *Cyprimeria sp.* and *Idonearca vulgaris* in abundance. In this fauna the large and ponderous specimens of *Gryphaea vesicularis* and *Exogyra costata*, with innumerable specimens of a variety of *Ostrea larva*, are a conspicuous faunal element for the first time, foreshadowing, perhaps, the Navesink fauna. The whole complexion of the fauna is different from either the Merchantville or the Woodbury, although certain species are present which occur also in one or both of these lower faunas.

Between the Marshalltown clay-marl and the "lower" or Navesink marl there is a well-marked sand bed 40–60 feet thick. In Monmouth County it is, on the whole, a fine micaceous sand, with some clay laminæ and locally near its base with thicker clay lenses. Locally its upper portion is a coarser quartz sand, with a commingling of glauconite near the marl bed. In the southern counties it is predominantly a coarse quartz sand with some disseminated glauconite, the fine micaceous phase being inconspicuous or even perhaps entirely absent. This formation Knapp called the Wenonah sand.

In Monmouth County Clark's Hazlet sands correspond exactly with Cook's "laminated sand," and almost exactly with Knapp's three formations—the Columbus sand, Marshalltown clay-marl, and the Wenonah sand—the upper few feet of the latter being apparently

| Cook, 1868 | | Clark, 1892–1904 | | Knapp-Kümmel, 1898–1904 | Weller, 1905 | |
|---|---|---|---|---|---|---|
| Upper Marl | Ash Marl<br>Green Marl | Manasquan | Manasquan Marl | Upper Marl (in part) | D | Manasquan |
| Yellow Sand | | | Yellow sand, later referred to the Miocene | Lime sand (including Yellow Sand) | C | Long Branch |
| Middle Marl | Yellow limestone and lime-sand<br>Shell layer<br>Green Marl<br>Chocolate Marl | Rancocas | Vincentown | | | Vincentown |
| | | | Sewell | Middle Marl (Sewell) | | Sewell |
| Red Sand | Indurated green earth<br>Red Sand<br>Dark micaceous Clay | Monmouth | Red Bank Sand | Red Sand (Red Bank Sand) | B | Tinton<br>Red Bank |
| Lower Marl | Marl and Clay<br>Blue shell Marl<br>Sand Marl | | Navesink Marl | Lower Marl (Navesink Marl) | | Navesink<br>Mt. Laurel |
| Clay Marls | Laminated Sands | Matawan | Mount Laurel Sand / Hazlet Sand | Wenonah Sand | A | Wenonah |
| | | | | Marshalltown Clay-Marl | | Marshalltown |
| | | | | Columbus Sand | | Columbus |
| | Clayey Green Sand | | Crosswicks Clay | Woodbury Clay | | Woodbury |
| | | | | Merchantville Clay-Marl | | Merchantville |

excluded. In the southern counties the Hazlet sands correspond only with Knapp's Columbus and Marshalltown, all of the Wenonah being excluded. The line, therefore, between the Matawan and Monmouth, as these two divisions were defined in 1897, is a line running diagonally across Knapp's Wenonah sand, from near the summit of that formation at Atlantic Highlands to its base in Gloucester and Salem Counties. This lack of agreement between the two interpretations was apparently due to Clark's interpretation of the relations of the coarse, quartz-sand phase of the Wenonah which he called the Mount Laurel sand. In regard to this formation he said:

> They have a thickness of about 5 feet in the vicinity of Atlantic Highlands, which slowly increases to the southward, until in the region to the east of Philadelphia they have increased to over 25 feet. Beyond that point they increase more rapidly throughout the southern counties, reaching 50 feet in Gloucester County and fully 80 feet in the vicinity of Salem.[1]

In New Jersey the lithological change at the top of the Wenonah is much more marked than that at its base, and for this reason the Wenonah sand was grouped by Knapp and Kümmel[2] with the underlying rather than the overlying beds. In effect, therefore, two positions for a major dividing line in this portion of the section have been suggested: (*a*) diagonally across the Wenonah sand; and (*b*) at the top of the Wenonah sand.

The recent paleontological studies cast some light upon this problem, even although they do not definitely settle it.

The Wenonah sand, so far as known at present, carries two different faunas. One of these has been found in Monmouth County, and at two localities from which extensive collections have been made over one hundred species have been recognized. This is very different from that in the overlying Navesink marl, and for the present will be referred to as the Wenonah fauna, although ultimately it may be best to give it a different name. The other fauna occurs in Gloucester and Salem Counties, and will be described in connection with that of the Navesink marl.

At one of the localities where the Wenonah fauna has been found the fossils occur in a coarse ferruginous sand at a distance of 9 feet

[1] *Annual Report of the State Geologist of New Jersey*, 1897, p. 183; also *Bulletin of the Geological Society of America*, Vol. VIII, p. 334.

[2] *Loc. cit.*

beneath the base of the Navesink marl. The other locality is in a fine, more micaceous and argillaceous bed, immediately beneath the marl.

In this Wenonah fauna there is a return of many Merchantville and Woodbury species, among them being *Trigonia eufaulensis*, *Axinea mortoni* and *Panopea decisa*. *Idonearca* is also present, but is much less conspicuous than in the Merchantville or the Marshalltown. Among the Woodbury species which occur in the Wenonah fauna, may be mentioned *Cymella bella*, which, although rarely present in the Merchantville, was much more conspicuous in the Woodbury fauua. *Leptosolen biplicata* is one of the very common forms in the Wenonah fauna which was present both in the Woodbury and the Merchantville. The ponderous *Gryphaea* and *Exogyra* of the Marshalltown fauna are absent, but *Ostrea plumosa* is sometimes a very common species.

The faunal change in passing from the Wenonah to the Navesink formations in Monmouth County is far greater than the change in passing over the line between any two of the formations below. In the fauna of the Navesink marl a new factor is introduced which is entirely foreign to the earlier faunas of the area, the most characteristic species of this new element being the cephalopod *Belemnitella americana* and the brachiopod *Terebratella plicata*, both of which are especially abundant and characteristic of this zone. We also find a recurrence of the massive *Gryphaea vesicularis* and *Exogyra costata* which characterized the Marshalltown beds below, but the *Exogyra* is usually less abundant than in the earlier fauna. *Ostrea larva* also occurs in great abundance, as it did in the Marshalltown fauna, but it is a somewhat different variety of the species. In place of the cephalopods *Placenticeras* and *Scaphites* of the "clay-marl" faunas, *Nautilus dekayi* occurs in this fauna and also in the fauna of the Red Bank sand next above. In the fauna of the beds just beneath the base of the Navesink marl, *Placenticeras placenta* occurs more frequently than in any other bed of the New Jersey Cretaceous, associated with many other species common also to the Merchantville or Woodbury formations. These facts, taken together with the marked lithological change at the top of the Wenonah, are strong evidence for placing the major dividing line in this portion

of the New Jersey Cretaceous at the base of the Navesink marl in Monmouth County. But there are other facts to be considered.

One of the most characteristic faunal features of the Navesink marl is a conspicuous shell bed about 12 feet above the base of the marl in Monmouth County. It is usually about 1 foot in thickness, and is composed almost exclusively of the shells of *Gryphaea vesicularis* and *Ostrea larva*, with occasional specimens of other pelecypods and gasteropods. At the base of the Navesink in Monmouth County there is sometimes an arenaceous, more or less abundantly fossiliferous bed, which Cook designated as the "sand-marl." At Atlantic Highlands this bed is 3 or 4 feet thick, and is evidently the bed which Clark mentioned in his description of the Mount Laurel sand at that locality, and which Knapp regarded as forming the top of his Wenonah sand. In passing to the southward this arenaceous basal member of the Navesink seems to become more and more conspicuous, replacing higher and higher beds of the green-sand marl, until at Mullica Hill it extends up to and even includes the conspicuous shell layer of the formation. This arenaceous facies of the Navesink frequently abounds in fossils, although they are usually imperfectly preserved casts, and the fauna is always characterized by the typical Navesink species *Belemnitella americana.*

It is believed that Clark's conception of the Mount Laurel sand formation has grown out from this changing facies of the Navesink to the southward, and, in the absence of sufficient data concerning the fauna of the beds immediately beneath those with the *Belemnitella* fauna, he has extended the Mount Laurel formation downward to include the entire sand bed to the top of the Marshalltown clay. On the other hand, Knapp and Kümmel have extended the Wenonah formation upward to include all the sand to the south, so that their upper boundary line of that formation marks a higher and higher geologic horizon in that direction. From the standpoint of the faunas the major division line in this portion of the Cretaceous beds must be drawn where the *Belemnitella* fauna is introduced, and although the Wenonah fauna of Monmouth County has not yet been detected in the more southern portion of the area, neither has the *Belemnitella* fauna been observed in the lower portion of this Mount Laurel-Wenonah sand, 18 feet beneath the top of the sand

being the lowest horizon where the *Belemnitella* fauna has been seen in New Jersey.

With this interpretation it is possible that both the terms, "Mount Laurel" and "Wenonah," should be retained in the nomenclature of these beds, the Wenonah for the sand formation beneath the beds bearing the *Belemnitella* fauna in Monmouth County and for the southern continuation of the same beds, while the name "Mount Laurel" will designate the arenaceous facies of the Navesink which becomes more and more conspicuous to the south. These relations, however, complicate the task of mapping the beds in the southern portion of the New Jersey area, because of the juxtaposition of the two arenaceous formations whose separation can be based only upon the presence or absence of the *Belemnitella* fauna. However, further observations upon these beds must be made before the relations here suggested can be considered as established.

The fauna of the Red Bank sand is to some extent a recurrence of the faunas of the beds beneath the Navesink marl, *Trigonia eufaulensis*, *Axinea mortoni* and other species of the Merchantville, Woodbury, and Wenonah formations being commonly present. Some species, such as *Perrisonota protexta* and *Corbula crassiplica*, which were present, although usually rare, in one or more of the "clay-marl" formations, become much more abundant in the Red Bank. The fauna is characterized everywhere by the large shells of *Gryphaea vesicularis* and by *Ostrea larva*, species which were abundant in none of these lower formations except the Marshalltown; but they never form such a shell bed as that which occurs so commonly in the midst of the Navesink marl. Other elements in the fauna are also inherited from the Navesink, although the two most characteristic Navesink species, *Belemnitella americana* and *Terebratella plicata*, have nowhere been observed in the fauna.

In none of the classifications as published, except Cook's, is any special recognition given to the hard, glauconitic, indurated sand bed at the top of the Red Bank, although it was briefly referred to by Clark, and has been carefully mapped by Knapp. This bed, called by Cook the "indurated green earth," marks a definite horizon and yields a fauna which especially characterizes it throughout its entire extent. The most characteristic member of this fauna is the

large ammonite *Sphenodiscus*, which has frequently been collected from this horizon, but has not been observed elsewhere. Another very characteristic species is *Trigonia caerulea*, which has been seen only in this formation, and almost everywhere the beds furnish numerous crustacean claws probably belonging to the genus *Callianassa*. A fine exposure of this formation occurs at Tinton Falls, N. J., where this hard bed, 22 feet thick, is responsible for a waterfall in a tributary of the Swimming River, and the name "Tinton beds" may be used to designate the formation. The fauna of the Tinton beds is much more closely allied to the faunas of the beds below than to those above, many of the earlier species being present, while *Terebratula harlani*, the most characteristic species of the next higher division, has never been observed.

Judging from their faunas, the three formations—Navesink (including that portion of the underlying sand with the *Belemnitella* fauna), Red Bank, and Tinton—constitute together a major division of the entire Cretaceous series, comparable in rank with the five formations of the "clay-marl" series, and Clark's name "Monmouth" very nearly expresses the limits of the division.

The Rancocas division of Clark, if some modification of interpretation be admitted, is another natural paleontologic division, characterized by the brachiopod *Terebratula harlani*, but the later investigations of the New Jersey Survey have thrown much light upon this portion of the Cretaceous section. The Sewell marl rarely contains fossils except at its summit, where a very constant shell layer of about 5 feet thickness occurs, being made up almost exclusively of the shells of *Gryphaea vesicularis* and *Terebratula harlani*. The Vincentown formation consists in large part of calcium carbonate furnished by immense numbers of several species of bryozoans. The remains of echinoids are also more or less common, and in the past some very fine specimens of these fossils have been found in this formation. The Vincentown fauna, however, is so different from that occurring at the summit of the Sewall marl that, were it not for the relationships of the "yellow sand" fauna, which combines both elements, one would scarcely be justified in including the Sewell and the Vincentown under one larger division.

In Cook's original classification of the Cretaceous beds of New

Jersey the stratigraphic position of the "yellow sand" was considered to be above the "lime sand" or Vincentown formation of Clark, and it was believed to be intimately related to that formation. But Clark, from his published statements, seems to have been somewhat uncertain in regard to the relationships of this bed.[1] It appears that, while at first he was inclined to follow Cook in including the "yellow sand" in the Cretaceous, yet at a later date he arrived at a different conclusion and considered the beds to be of Miocene age.

A careful search by the writer, in company with Knapp, disclosed good fossils in the "yellow sand" at several localities, and fragments of fossils may be found in the formation at almost every exposure. At the base of Gold Hill, one mile south of Eatontown, *Terebratula harlani* and *Gryphaea vesicularis* occur in abundance, and with them fragments of spines and plates of echinoids, and broken bryozoans. At California Hill, near Deal, fossils occur near the summit of the formation in abundance, *Terebratula harlani* again being the most common form, associated with several species of pelecypods. In the bank of the Manasquan River, at New Bergin Mills, one and one-half miles west of Farmingdale, this formation is well exposed in an unweathered condition, and contains a somewhat larger percentage of glauconite than in the other localities mentioned. Fossils are exceedingly abundant at this locality, some layers of the sand being filled with bryozoan remains, with some echinoids, the fauna being essentially that of the Vincentown lime-sand. In other beds at the same locality, fragments of *Terebratula harlani* were observed.

I have interpreted these fossils as definite evidence that the sand in which they occur is of Cretaceous age, and is to be correlated with the Vincentown lime-sand. If it be thought worth while to designate the "yellow-sand" facies of this formation by a separate name, it may be called the "Long Branch sand," as has been suggested by Knapp.

Clark's contention that the "yellow sand" is Miocene in age is based upon the supposition that the present position of the included fossils is not their original position, but that they have been washed

[1] *Annual Report of the State Geologist of New Jersey*, 1892, p. 205; *ibid.*, 1893, p. 338; *ibid.*, 1897, p. 186; also *Bulletin of the Geological Society of America*, Vol. VIII, p. 336; and *Annual Report*, 1897, p. 190; also *Bulletin*, Vol. VIII, p. 340.

out from their original place of deposition, and have been redeposited in these sands in Miocene time. This interpretation, however, seems to be untenable on account of the stratigraphic relations of the beds, on account of their geographic distribution, and on account of the difference in character between these beds and the dark clay beds which form the base of the undisputed Miocene in the adjacent region. Furthermore, wells drilled to the south of the outcrop of the "yellow sand" show the presence of a similar arenaceous bed beneath the Manasquan marl.

If the reference of these beds to the Cretaceous is correct, it shows that the *Terebratula harlani* zone has a much greater vertical range in New Jersey than the shell bed at the summit of the Sewell marl, in this respect corresponding with the conditions in Maryland where, Clark says, "the *Terebratula harlani* is no longer limited to its former horizon at the top of the Sewell marls, but occurs frequently within and even at the top of the lime-sands."[1]

As regards the "upper" or Manasquan marl of Clark, there is no difference of opinion, except as Clark's earlier interpretation of the "yellow sand" affected the lower limits of the formation in his original definition. The fauna differs in most of its species from the lower faunas, *Caryatis veta* and *Crassatella delawarensis* being two species usually found in this horizon and not observed elsewhere. The bed is especially characterized by the large number of sharks' teeth it contains. The higher beds of the "upper marl," separated by Clark as the Shark River formation, are recognized, by everyone who has studied them, as of Eocene age, and therefore they need no further consideration here.

From the view-point of the writer, the arrangement of the formations, as expressed in the fourth column of the table on p. 76, seems best to express the true faunal relationship of the beds. With the exception of the Tinton beds and the Long Branch sand, no new names are introduced. For the designation of the four major divisions the letters A, B, C, and D are used, instead of Clark's four names "Matawan," "Monmouth," "Rancocas," and "Manasquan," these divisions being strictly faunal, while Clark's names were proposed to designate stratigraphic divisions.

[1] *Annual Report of the State Geologist of New Jersey*, 1897, p. 189; also *Bulletin of the Geological Society of America*, Vol. VIII, p. 339.

In conclusion, the following summation of results in connection with recent investigations upon the Cretaceous formations and faunas of New Jersey may be made.

1. Cook's classification fully differentiated all the beds of the "marl" series that have been recognized since his investigations were carried on, but the "clay-marl" series has been more fully divided since his work was completed. He was in error, however, in applying his classification to the southern counties.

2. In the discrimination of beds, Clark's classification is in the main that of Cook, his contribution being a modernization of the older classification by the introduction of geographic formation names for Cook's lithologic names, and a grouping of the formations into larger divisions.

3. In so far as the discrimination of beds is concerned, Knapp's differentiation of the "clay-marl" series is a distinct advance over the earlier classification.

4. A study of the paleontology of the "clay-marl" formations of Knapp shows them to be as fully differentiated by their faunas as by their lithologic characters.

5. For both faunal and stratigraphic reasons, the "indurated green earth" of Cook is separated from the Red Bank sand, and is recognized as a distinct formation to which the name Tinton beds is applied.

6. The "yellow sand" is regarded to be of Cretaceous age, as originally interpreted by Cook, and its fauna to be the equivalent of that of the Vincentown lime-sand.